

PHOTOGRAPH DESCRIPTIONS


Darwin, Northern Territory, Australia
February 9, 10, 11, 1975

Dr. Marshall and I arrived at Darwin on Saturday, the eighth of February, 1975 about 5 P.M., central Australian time. We were met at the airport by Dr. George Walker of the James Cook University of North Queensland and Mr. Geoff Anderson, Director of the Experimental Building Station, Department of Housing and Construction in Sydney. We proceeded directly to the Travelodge Hotel where accommodations had been arranged for us.


On Sunday morning, February 9, 1975 we took our initial tour of the damage scene in Darwin. We began in the northern suburbs, close to the corner of Bell Street and Trobe Street. This area is new residential construction (less than two years old); perhaps the newest in residences in Darwin.

DO *Map of Darwin*

Photo No.	Descriptions: February 9, 1975
✓ D1	A concrete block house. Vertical reinforcing: one steel bar in the corner close to where Dr. Marshall is standing. Four people were killed in this house.
✓ D2	Concrete block house across the street from house in D1. Notice the gap in the masonry wall between the concrete block and the brick facing.
✓ D3	View of the same house (in D2) from another angle.
✓ D4	A low-set house with bond beams consisting of concrete poured into U-shaped blocks. Notice the wall has fallen outward to the east. The bond beam was not anchored to the wall. This was probably Darwin Housing Commission housing.
✓ D5	Looking north and east in this northern suburb housing area.
✓ D6	The rear of a Housing Commission house showing how the roof was lifted off. The bond beam in the center of the picture went with the roof. There was no tie between the bond beam and the top of the wall.
✓ D7	A wide angle shot looking south and west toward a high-set house. Notice the platform, which includes concrete piers, is skewed toward the south.
✓ D8	The south elevation of a private house built with brick. Outside walls are two layers of brick with a cavity.

- ✓ D9 The windward or north elevation of the same house. Cast, asbestos roofing on battens; truss roof construction.
- ✓ D10 Fasteners from the gang nailed truss to the top of the wall: wall line.
- ✓ D11 Fastener at the eave line. Brackets are referred to as "triple grip;" it is believed that they were introduced in Darwin by TICO.
- ✓ D12 Detail of a brick veneer house which has a steel frame. Note the framing members at the top of the wall and the triple grip fasteners holding the truss to the steel frame.
- B&W only* D13 An overall view of the same house. The tile roof is new.
- ✓ D13A (No number shows in photograph). Shows the same wall detail as did D12.
- ✓ D14 The steel framing detail over the carport area. The steel beams were anchored with 1/2 inch anchor bolts to the columns. This house got into trouble only in the tile roof and that because of debris impact, initially, rather than by lifting due to the wind. The owner reports this house to be three months old.
-  D15 A close up of some battens showing the screws which are driven through the sheetmetal roofing to anchor the roofing to the battens. The battens are, in turn, connected to the rafters.
- D16 An example of metal roofing showing the holes where the screws have pulled out.
- D17 A high-set house with unique metal panels nailed to the end wall. Note the three screw lines which make the end wall quite effective in carrying shear. Notice also the strap exposed in the plane of the end wall.
- D18 This photo shows how attempts were made using cyclone bolts to hold the roof to the wall and the wall to the platform. There are 3/8 inch cyclone bolts over the windows; there should have been cyclone bolts at the edge of the windows like those seen at the edge of the door.
- D20 A close up of the truss to plate detail.
- D21 Note a steel strap hanging right below the D21 sign which was supposed to be the tension strap providing shear resistance in this the south wall. Notice on the east face the corrugated metal performing effectively in shear. (Note: Mr. Gamble subsequently indicated that these straps are for "squaring" the panel and were not intended to carry shear.)

Black & white only



B&W
only

D22 General shot of a high-set house where we had discussions with the owner.

✓ D23 A rafter to wall detail. Note the presence of a cyclone bolt and an iron strap that goes over the steel strap.

✓ this
slide is
lost somewhere.
be on lookout for it!

D24 The west wall: note the steel strap running upper right to lower left, which would have been a strap working in compression. The corresponding tensile strap failed or, in any case, is not evident.

✓ D25 Looking south and west. House in foreground is concrete block house that was photographed in D1.

✓ D26 Another cyclone bolt detail with a quarter-inch steel flat welded to the cyclone bolt. This wall came from the house photographed in previous slides.

✓ D27 Typical electric power distribution pole which has failed. Light standards in the background did not fail.

✓ D28 Wide angle shots, adjacent fields of view: the first photo
✓ D29 to the south, the second to the south and east. In D29 you can see in the center of the photo the privately financed house that had the steel frame. The sheet iron enclosures on top of these houses enclose the header tank for solar heated water.

✓ D30 Looking north and west toward the open sea, from this the edge of the northern suburb. There is a rise coming this way--the winds that devastated this housing area came from the northwest.

✓ D31 Close up of a cyclone bolt detail.

✓ D32 Detail of a high-set house, which has timber bracing on top of concrete piers. The whole house is skewed to the south and east (as can be seen in D33).

✓ D33 A house at the northern and western edge of the northern suburbs. This house is skewed to the south and east on its concrete piers.

B&W only

D34 Looking south and east toward a welfare home for unmarried mothers. This engineered structure is perhaps the one closest to the sea and may well have born the brunt of the winds. Notice no windows are broken on the west side, some windows broken on the second floor. Evidence of corner uplift can be seen to the right side of the wind that projects to the east.

B&W only

D35 Looking north across the street from the welfare home, showing, again, some high-set houses skewed to the south and east.

B&W
only

D36 A high-set house which has been shoved off of its piers, this one falling toward the north. Notice the clips which housed the roofing material, trade name Klip-Lock. All the roofing is gone, leaving the clips. Steel beams span across the tops of the concrete piers.

✓ D37 (Number not in photograph.) A view of the Travelodge failure: failure of brick veneer facing.

✓ D38 A ship that impacted the seawater outlet works of the Darwin Power Station. This incident and a barge impacting the intake works were actually the determining factor in getting the power plant back into full operation.

B&W only

D39 Stokeshill Power Station. Some water damage occurred inside due to failure of the roofing material, but Mr. Redman reports that power station performed well.

B&W only

D40 Switching Station at the Stokeshill Power Station. Some lines down, but no structural damage occurred at this switching station.

✓ D41 Prestressed transmission line towers: failed at the base.

✓ D42 Mr. Redman reports that the power company lost almost 100% of the towers of this type that had wires on them at the time of the cyclone.

D43 Broken transmission line showing the strand recoil. All but one strand broke.

D44 Light standard wrapped with sheet metal. A row of six or seven of these poles failed, while poles on either side did not, apparently due to the heavy debris load.

D45 This photo shows the detail of these poles. A circumferential weld about 5 1/2 feet off the ground and a longitudinal seam weld above that point. This row of six or seven poles all failed at the same height above the ground. This view is on McMillans Road. The sheet steel wrapped around these poles is the Klip Lock style of roofing material.

D46 Another type of transmission tower. The tower failed to the right of the picture (which was actually in the direction corresponding with maximum wind) and was then dragged off of the road into the position shown. A row of these towers failed leading some to believe that a failure at one point precipitated sequential failures along the line in towers away from the initial point of the break.

D47 A gasoline station shed on McMillans Road which didn't fail. Across the street from this gasoline station is a precast prestressed transmission tower which shows some cracking but did not fail.

B&W only

BEW only

- ✓ D48 The brick wall on the gasoline station that failed outward, after overhead doors to the windward side had failed allowing wind to enter the building.
- ✓ D49 The door wheel and detail showing how the wheel pulled out of the channel. The lip of the channel is bent as can be seen in the lower part of the picture.
- ✓ D50 A bottle shop still in operation; here we purchased our stock of Australian lager.
- ✓ D51 Dick Marshall and Geoff Anderson purchasing supplies. Also Arch Jones.
- BEW only* D52 An electric power substation. Wires seem to be broken but no structural damage is evident. This substation is on Trower Road. The road runs due north at this point.
- ✓ D53 Ensuing photos are at Darwin Community College. Here the columns failed as did the four open web steel joists in the plane of the roof. Dr. Walker feels that uplift on the roof pulled the columns in a manner such that they failed in tension on their outer side. He feels that there was considerable dynamic uplifting which caused compression failures in the bottom chords of the joists.
- ✓ D53A Shows the failure in the column.
- ✓ D54 Shows the lateral buckling of the compression bars in the roof joist.
- ✓ D55 Anchorage detail at the end of the open web steel joist.
- ✓ D56 View along the leeward wall on the second floor. The concrete block failed outward along this wall, which was perhaps four feet inside of the column line.
- ✓ D57 Shows a cavity anchor which stayed with this steel frame. The wall failed outward, apparently.
- ✓ D58 General view of the west wing which was longer than the east wing previously photographed. This wing did not have the complete second floor failure.
- ✓ D59 A Panel failure. Apparently, the window frame went in causing the failure in the "fill-in" wall.
- ✓ D60 A window which may have failed due to wind pressure alone. Notice the 45° angle cracks.
- ✓ D61 A diagonal crack in a wall which on the backside is concrete block. The interesting observation here is that the crack in the concrete block on the back side follows the mortar joint, whereas on the near side it is a perfect 45° crack.

See Weekly

- D62 The top of the column at the first floor level where bars had been lapped to go to the second floor. The column has been removed from the scene.
- ✓ D63 This view is along the line of columns that is the interior wall, showing, particularly, the anchorage failure at the top of the columns. Previous pictures show the anchorage detail.
- ✓ D64 The corner of the short wing. This wall apparently fell outward although debris has been removed.
- ✓ D65 The leeward wall of the long wing or (west wing).
- D66 Views to the south at residential housing on the campus.
- ✓ D67 { Showing the windward wall of part of the faculty housing for
- ✓ D68 { Darwin Community College. This windward wall failed inward
- ✓ D69 { at a level below the anchorage which extends downward from the roof in the cavity between the two layers of brick.
- ✓ D70 A second floor end wall which fell inward. The room adjacent to this end wall failure shows purlins buckling upward over that second span.
- ✓ D71 The distress in the inner layer of brick was caused, apparently, by roof uplift pulling along the ridge line at the top of the brick wall.
- ✓ D72 A wall displaced laterally along the horizontal flashing located at the second brick course above the ground.
- ✓ D74 These three photos show a house which was pushed completely
- ✓ D75 off of its piers, landing on top of two cars.
- ✓ D76

SUMMARY OF ACTIVITIES

Sunday, February 9, 1975

The morning was spent in northern suburbs on Trower Street in the vicinity of Bell Drive. These houses, according to Dr. Walker, are the newest in Darwin. In fact, many were still under construction at the time of the cyclone. These houses fared badly. Dr. Walker is not prepared to concede that this severe damage is because windspeeds were greater in this area. He seems to feel, at this point, that the most recent construction practice was less resistant to cyclone winds than was earlier construction which we will view on Monday.

[Note: A few unnumbered photos of government buildings were taken in downtown Darwin showing, particularly, solar screens which act effectively in arresting missiles and in preventing glass and curtain wall damage.] (SEE SUPPLEMENTAL SHEET)

Photo No.

Descriptions: February 10, 1975

- ✓ D77 A view of an apartment house. Notice the top floor roof is a concrete deck. Dr. Walker reports that this was the only apartment flat in Darwin that escaped major damage. This location is close to the intersection of Trower Road and Sabine Road.
- ? in system; watch for this* ✓ D78 A school across the street from the apartment house. This temporary classroom building was pushed off of its foundation but remained intact. Geoff Anderson reports the basic failure was one of foundation. The entire building is metal, seemingly working very effectively as stressed skin construction.
- ✓ D79 Detail of the foundation. The strap visible in D79 passed over the I beam and was bolted to the footing. There was no weld apparent between the strap and the beam.
- ✓ D80 Inside the gymnasium of the school. The roof paneling was clip locked. There were walls outside of the columns that can be seen that were made of brick. The brick walls failed and have been removed.
- ✓ D81 Still at the school. More temporary sheet metal type of construction. In this case the foundation was larger blocks with a plate anchored to the bottom flange of the supporting beams.
- ? in system; watch for this* ✓ D82 A close up of the beam to footing detail.
- ✓ D83 View along a wall on the second floor of the school building. The cavity brick wall collapsed onto the stairwell to the left.
- ✓ D84 View due west from the second floor of the school. Notice a movie screen in the left part of the photograph which, according to Dr. Walker, was designed for 150 mile per hour winds. The maximum wind would have acted on that screen face on from the far side.
- ✓ D85 View south toward Darwin City Center, the Travelodge is immediately to the left of tree in center foreground.
- ✓ D86 South and east elevation of the apartment house which survived without major damage. Klip Lock roofing detail in foreground has some connectors between the ribs of the roofing material and the brackets. Mr. Anderson reports this is no longer done.

- ✓ D87 Shows the roof detail. The dimples are visible along the near edge. The roof system is called "Brown built". Mr. Anderson reports that Klip Lock bought out the Brown system.

[The photo series just completed is Millner Primary School.]

- ✓ D88 General view of Millner Primary School looking south and west.
- ✓ D89 View of a steel (pre 1968) high-set. Notice missile impacts in west wall and cross bracing in between steel piers.

[We have moved into the Moil area off of Trower Road, actually Lemon Street in Wagaman. This housing is vintage 1970. D90 starts a series of precast concrete houses.]

- ✓ D90 View of precast concrete house. The columns and beams are precast and connected together. The roof is precast although not very effectively tied to the tops of the walls, seemingly one batten board along the edges held the roof to the tops of the walls.

- Biz. Wonly* ✓ D91 Shows roof beam connection. There seems to be provisions for bolts to tie the roof down but no bolts are evident.

- ✓ D92 Roof of the precast concrete house. Shows concrete block panel details. There were provisions to tie these panels to the walls at the points of the columns. There is no evidence of such connections. Notice hexagonal nuts cast into tops of beams. Mr. Anderson believes this may have been for battens to hold down the roof sheeting.

- ✓ D93 Wide angle shots looking to the north and northwest. Housing in foreground is privately financed. Note house in center of
- ✓ D94 D94 has very large spans between piers. In fact, this house has only two rows of piers.

- ✓ D95 Looking back to the south from the same point as D93 and D94. Precast concrete house is in left foreground. Low-set housing to the right.

- Biz. Wonly* ✓ D96 Corner of a precast house showing the windward wall which failed inward. The beams that met in the corner are hanging loose. The mode of failure is not clearly understood.

- Biz. Wonly* ✓ D97 Shows the bottom of the column that was on the corner of the previous slide.

- ✓ D98 ~~(Omitted)~~ Detail onto which column fitted at top of 1st story

Be. Wonly

D99

A view of the house in which an architect and his family of 3 were killed. Notice the floor came completely off of the piers.

Be. Wonly

D100

On Lions Street in the extreme northeastern suburb. This low-rise has steel trusses and some kind of fiber glass paneling in a sandwich construction.

✓ D101

A missile penetrating this sandwich wall construction--some kind of a foamed material surfaced on both sides with a gypsum like sheeting.

Be. Wonly

D102

Photo shows wall construction. There are steel members within the wall panels, as can be seen to the right in the hole.

[This area is Wanguri, three blocks down from Tambling Terrace.]

✓ D103

A pine framed house. Dr. Walker reports that the roof and walls were all timber except for the rear wall which was concrete block. In his opinion--almost certainly the concrete block failed leading to the progressive failure of the remainder of the house. Actually, the roof and walls would have performed very effectively in shear.

Be. Wonly

D104

General damage scenes in this same area as the pine wood house. These views show high-set structures, mostly recent construction. Steel beams on concrete piers are evident.

D105

✓ D107

Inside an industrial building near the airport. This sawtooth roof experienced winds from a direction which would load the trusses shown "in plane." The triangular trusses failed downward within their own plane.

✓ D108

A truss in the second bay from the windward side which shows evidence of buckling in the lower chord. (The number 108 may not show in the picture.)

Be. Wonly

D109

Windward wall showing that the columns moved inward, causing buckling downward in the sawtooth trusses.

✓ D110

Shows the truss has buckled downward causing a diagonal member to fail in tension. Notice that there was lateral bracing to the bottom chord of the truss so the truss had to buckle in its own plane.

[Note there is no D111]

✓ D112

Another view of the failed sawtooth truss. This diagonal member failed as well. There are diagonal angles in the plane of the roof. It appears that these angles would have transferred the load to the center column which is apparently the point at which failure first occurred. The sawtooth truss behind the center column failed first, leading to the subsequent failure of adjacent trusses.

- ✓ D113 Looking face-on to the windward wall. View is looking almost directly north. This location would be south of the eye of the cyclone. The eye would have passed right over this location, so second-half winds would have caused this damage. Dr. Walker feels several factors confirm an observation that second-half windspeeds were higher than first-half windspeeds:
 - (1) south direction from this point is over an arm of the sea and there is less resistance to south wind than to winds coming from the north (just before the passage of the eye),
 - (2) roofing loss from metal buildings in the area tend to confirm higher south winds as more cladding seems to be lost along windward eaves and ridge lines when the windward direction was south.

- ✓ D114 North wall of the same industrial building showing leeward wall failure. The blocks collapsed outward from the top onto the driveway below.

- ✓ D115 Shows cladding peeling from a corner of an industrial building. This would be the north face of that building.

- ✓ D116 An adjacent industrial building showing differences in frame design. Dr. Walker and Mr. Anderson indicate these are consulting engineer designed structures and, in general, the frames performed very well.

- ✓ D117 Yet another example of industrial building design. This structure has truss work extending down the columns lines to act as wind bracing. Here, again, had the cladding stayed with the building the frame and building probably would have survived.

- ✓ D118 *Industrial Bldgs*
- ✓ D119 Another metal frame building comprised of cold formed channels with a tubular knee brace at the eave line and a tubular brace at the ridge line. The two channels arranged back to back forming the principal framing members (let's call them rafters) were not connected so as to act together.

- ✓ D120 Inside view of collapsed structure.

- ✓ D121 Looks along a rafter which is cold formed channels. Notice that there are connections only where the tubular bracings intersect to the channel member.

- ✓ D122 General view of same building.

- ✓ D123 At a different industrial building, but one that was built very much the same way. Notice the back to back cold formed channels have no connections which would transmit shear, one channel relative to the other.

- ✓ D124 A wide angle shot along the ridge line of the building. Note the ridge line detail next to the D124 number.
- ~~D125~~ D125 The column portion of the frame. Notice only two bolts in each batten plate, the batten plates are, perhaps, five feet apart.
- ✓ D126 Shows the detail for the wind bracing in the end panel (the panel between the end frame and the first interior frame). A similar angle in the opposite corner just "opened" as the structure failed.
- ~~D127~~ D127 The same detail at the bottom of the column of the first interior frame. The building is a "Baraweld" Building (an offshoot of a Canadian Firm, ATCO).
- ✓ D128 Shows a truss type, framed industrial building. The end wall was free standing masonry and has failed inward. The purlins between the first interior frame and the second interior frame on the east end have buckled upward, reflecting both roof uplift and direct compression load carried in the purlins.
- ✓ D129 *Same Bldg different view*
- ✓ D130 Next door to the east. A rigid frame building had an end frame but the X bracing in the first panel failed in compression forcing a load transfer to the purlins in the roof; the purlins failed in stability.
- ✓ D131 A wide angle shot of the same building. You can see both the remains of the X bracing in the first panel from the right end as well as buckled purlins spanning from the end frame to the first interior frame.

Ends photographs taken on Monday.